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May 6, 2004
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Case No. 9281-4241
ALPS Ref. No. N US00123

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:	
Masayoshi Nakagawa et al.	Examiner: C.R. Magee
Serial No.: 10/043,739	
Filing Date: January 9, 2002	Group Art Unit: 2653
For: MAGNETIC HEAD ACTUATOR HAVING FINELY MOVABLE TRACKING DEVICE	

SUBMISSION OF CERTIFIED ENGLISH TRANSLATION

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Dear Sir:

Submitted herewith is a certified English translation of Japanese Patent Application No. 2001-003882, filed January 11, 2001. The above-referenced U.S. patent application claims benefit of priority under 35 U.S.C. § 119 to the accompanying translated Japanese Patent Application. The applicants previously filed a certified copy of their Japanese priority application on January 9, 2002.

Respectfully submitted,

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DECLARATION

I, Takehiko IWAHANA, hereby declare that I am fully conversant in English and Japanese and that the attached is an accurate translation of Japanese Patent Application No. 2001-003882 filed in the Japanese Patent Office on the 11th day of January, 2001.

Signed this 19th day of April, 2004

Takehiko Iwahana

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[Name of Document] Application for Patent

[Reference No.] P4345

[Addressee] Commissioner of the Patent Office

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[List of Documents Attached]

[Name of Document] Specification 1

[Name of Document] Drawings 1

[Name of Document] Abstract 1

[Proof] Required

[Name of Document] SPECIFICATION

[Title of the Invention] MAGNETIC HEAD ACTUATOR EQUIPPED WITH FINELY MOVABLE TRACKING DEVICE

[Claims]

[Claim 1] A magnetic head actuator including a finely movable tracking device comprising:

a swing arm having a magnetic head formed at the free end thereof and being reciprocally movable about a coarse rotating axis of the base thereof;

piezoelectric elements fixed in the swing arm and causing the free end of the swing arm to move finely about the coarse rotating axis in the arcuate direction when a voltage is applied thereon; and

an FPC board having feeding lines disposed on a resin base, each for feeding power to a voltage-applying electrode of the corresponding piezoelectric element,

wherein the feeding line of the FPC board is arranged to extend onto the corresponding voltage-applying electrode, and a portion of the resin base extending on the voltage-applying electrode of each piezoelectric element is removed so as to directly electrically connect the feeding line to the voltage-applying electrode at this resin-base-removed-portion.

[Claim 2] A magnetic head actuator including a finely movable tracking device comprising:

a swing arm having a magnetic head formed at the free end thereof and being reciprocally movable about a coarse rotating axis of the base thereof;

piezoelectric elements fixed in the swing arm and

causing the free end of the swing arm to move finely about the coarse rotating axis in the arcuate direction when a voltage is applied thereon; and

an FPC board having feeding lines disposed on a resin base, each for feeding power to a voltage-applying electrode of the corresponding piezoelectric element,

wherein the feeding line of the FPC board is arranged to extend onto the voltage-applying electrode of each piezoelectric element in a manner of being held to the FPC board before being connected to the piezoelectric element, so as to directly electrically connect the extended portion of the feeding line to the voltage-applying electrode.

[Claim 3] The magnetic head actuator according to Claim 1 or 2, wherein the feeding line and the corresponding voltage-applying electrode are bonded to each other by ultrasonic bonding.

[Claim 4] The magnetic head actuator according to Claim 1, wherein the feeding line and the corresponding voltage-applying electrode are bonded to each other by gold-ball bonding.

[Claim 5] The magnetic head actuator according to Claim 1 or 2, wherein a portion of the resin base extending on and under the feeding line lying on the corresponding voltage-applying electrode is partially removed, and the feeding line has a through-hole formed at this resin-base-removed-portion so as to electrically connect the feeding line to the voltage-applying electrode of the piezoelectric element by gold-ball bonding extending through the through-hole.

[Claim 6] The magnetic head actuator according to Claim 5, wherein the piezoelectric element has a stud bump previously formed thereon, composed of conductive material, and the stud bump extends through the through-hole of the feeding line so as to establish electrical connection.

[Claim 7] The magnetic head actuator according to one of Claims 1 to 5, wherein the piezoelectric elements are a pair of piezoelectric elements having mutually reverse polarities.

[Claim 8] The magnetic head actuator according to one of Claims 1 to 6, wherein the FPC board has trace lines integrally formed thereon, leading to a magnetic head.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to a magnetic head actuator including a finely movable tracking device, and more particularly, it relates to the power feeding structure of the tracking device to piezoelectric elements of the same.

[0002]

A magnetic head actuator widely used in an HDD has a magnetic head facing a rotating hard disk, disposed at the free end of a swing arm swinging reciprocally about the rotating axis of the base thereof and causes the swing arm to swing about the rotating axis in accordance with a tracking signal from the hard disk. In order to meet the demand for a narrower track width or a smaller track pitch, a finely movable tracking device is constructed such that piezoelectric elements (piezo elements, PZTs) expanding and

contracting in response to an applied voltage are fixed in the swing arm so as to cause the free end of the swing arm to move finely about the rotating axis of the arm in the arcuate direction in response to expansion and contraction of the piezoelectric elements.

[0003]

In a conventional magnetic head actuator equipped with the finely movable tracking device, a ground electrode of each piezoelectric element is electrically connected to the swing arm, and power is supplied to a voltage-applying electrode extending along the swing arm, via a feeding line of an FPC board. The feeding line of the FPC board and the corresponding voltage-applying electrode of the piezoelectric element are connected to each other by known gold-wire bonding (Au-wire bonding).

[0004]

However, wiring by the gold-wire bonding has well known problems in that the gold-wire bonding is not only expensive due to many man-hours required but also easily broken by an external force because of a thin wire of an order of micrometers in diameter. In particular, a component such as a magnetic head actuator incorporated into an HDD in an additional step after assembly has a problem in that its wiring is easily broken, thereby leading to continuity defects and a low yield.

[0005]

[Object of the Invention]

Accordingly, it is an object of the present invention to

provide a magnetic head actuator equipped with a finely movable tracking device facilitating wiring to piezoelectric elements, while reducing problems such as wire breakage and continuity defects of wiring.

[0006]

[Summary of the Invention]

The present invention has been made on a basis of an idea in that, in order to mutually connect a voltage-applying electrode of each piezoelectric element and a corresponding feeding line of an FPC board without gold-wire bonding, the feeding line of the FPC board is arranged to extend onto the voltage-applying electrode, and a portion of a resin base is removed, so as to electrically and mechanically connect the feeding line and the corresponding voltage-applying electrode to each other at this resin-base-removed-portion by ultrasonic bonding, gold-ball bonding or stud bumping.

[0007]

A magnetic head actuator according to the present invention includes a finely movable tracking device including a swing arm having a magnetic head formed at the free end thereof and being reciprocally movable about a coarse rotating axis of the base thereof; piezoelectric elements fixed in the swing arm, causing the free end of the swing arm to move finely about the coarse rotating axis when a voltage is applied thereon; and an FPC board having feeding lines disposed on a resin base, each for feeding power to a voltage-applying electrode of the corresponding piezoelectric element. The feeding line of the FPC board is arranged to

extend onto the corresponding voltage-applying electrode of the piezoelectric element, and a portion of the resin base extending on the voltage-applying electrode of each piezoelectric element is removed so as to directly electrically connect the feeding line to the voltage-applying electrode at this resin-base-removed-portion.

[0008]

In another aspect of the present invention, the feeding line of the FPC board is arranged to extend onto the voltage-applying electrode of each piezoelectric element in a manner of being held to the FPC board before being connected to the piezoelectric element, so as to directly electrically connect the extended portion of the feeding line to the voltage-applying electrode.

[0009]

For example, ultrasonic bonding, gold-ball bonding or the like can be used as specific electrical conduction means (mechanical and electrical connection means).

[0010]

Preferably, a portion of the resin base extending on and under the feeding line lying on the corresponding voltage-applying electrode of the piezoelectric element is partially removed. Thus, the feeding line has a through-hole formed at this resin-base-removed-portion and is electrically connected to the voltage-applying electrode by gold-ball bonding extending through the through-hole. Alternatively, the piezoelectric element has a stud bump previously formed thereon, composed of conductive material, and the stud bump

is inserted through the through-hole of the feeding line so as to establish electrical connection.

[0011]

Although the swing arm works theoretically with a single piezoelectric element, the swing arm is practically equipped with a pair of piezoelectric elements having mutually reverse polarities so that the magnetic head makes a larger movement.

[0012]

Although the FPC board having the feeding lines leading to the corresponding piezoelectric elements may be prepared separately from that having trace lines leading to the magnetic head, the FPC board is commonly used in practice for these lines.

[0013]

[Description of the Embodiments]

Fig. 1 shows an overall structure of an HDD equipped with a magnetic head actuator according to embodiments of the present invention. Outside a hard disk (magnetic disk) 12 rotating about a rotating axis 11, the base of a swing arm 20 (a load beam, a gimbal spring) is supported in a reciprocally swinging manner about a coarse rotating axis 13. A magnetic head (flexure) 21 is supported at the free end of the swing arm 20, and, when the swing arm 20 is reciprocally swung about the coarse rotating axis 13 by an actuator 14, the magnetic head 21 moves reciprocally in the substantially radial direction of the hard disk 12.

[0014]

A pair of piezoelectric elements 22 having mutually

reverse polarities are mounted in the swing arm 20 so as to extend parallel to and on both sides of a linear line connecting the coarse rotating axis 13 and the magnetic head 21 to each other. As shown in Figs. 1 and 3, each piezoelectric element 22 has a ground electrode 22G on one of the front and rear surfaces thereof and a voltage-applying electrode 22V on the other, and, when the same voltage is placed across the ground electrode 22G and the voltage-applying electrode 22V of the piezoelectric element 22, the polarizing directions of the piezoelectric elements 22 are set such that one of lengths L extending parallel to the linear line mutually connecting the coarse rotating axis 13 and the magnetic head (flexure) 21 expands while the other contracts.

[0015]

In order for expansion and contraction of the pair of piezoelectric elements 22 in the direction of the length L to be transmitted to the swing arm 20, the swing arm 20 has a pair of spaces 20S (Fig. 3) formed therein for accommodating the piezoelectric elements 22, and insulating non-shrinkable resin 24 is filled in clearances between both ends of the piezoelectric element 22 in the length L direction and the spaces 20S. When one of the piezoelectric elements 22 expands while the other contracts, the pair of piezoelectric elements 22 bonded to the swing arm 20 as described above cause the end (the magnetic head 21) of the swing arm 20 to move finely in the arcuate direction about the coarse rotating axis 13. When each piezoelectric element 22 expands

and contracts by, for example, 1 μm, the current technology level permits the magnetic head 21 to move finely by about 10 μm in the arcuate direction about the coarse rotating axis 13. As shown in Fig. 4 by way of example, the ground electrode 22G is electrically connected to the swing arm 20 composed of metal (conductive material) by electrically conductive resin 25 so that the swing arm 20 is grounded.

[0016]

An FPC board 30 commonly used for the magnetic head 21 and the piezoelectric elements 22 have trace lines 32 leading to the magnetic head 21 and feeding lines 33 leading to the corresponding piezoelectric elements 22 disposed on a resin base 31 (typically formed of polyimide resin). Each trace line 32 is connected to the magnetic head 21 at one end thereof and to a record-playback circuit 15 at the other end thereof. Each feeding line 33 is connected to the voltage-applying electrode 22V of the corresponding piezoelectric element 22 at one end thereof and to a control circuit 16 at the other end thereof. The control circuit 16 is connected to the actuator 14. The actuator 14 and the piezoelectric elements 22 are controlled in accordance with control signals transmitted from the control circuit 16, the magnetic head 21 receives tracking signals from the hard disk 12 and inputs them into the control circuit 16 while exchanging record (playback) information signals with the record-playback circuit 15 at the same time, and the control circuit 16 controls the actuator 14 and the piezoelectric elements 22 so that the swing arm 20 (the magnetic head 21) lies in a proper

track position.

[0017]

The present embodiments have a feature of a connecting structure in which the piezoelectric elements 22 of the magnetic head actuator and the corresponding feeding lines 33 are connected to each other as described above. As described previously, the piezoelectric element 22 and the feeding line 33 are conventionally connected to each other by gold-wire bonding, thereby causing problems of high cost and wire breakage.

[0018]

Figs. 4 to 9 illustrate a first embodiment of the present invention. The resin base 31 and the feeding lines 33 of the FPC board 30 are arranged to extend onto the voltage-applying electrodes 22V of the piezoelectric elements 22, and a portion of the resin base 31 extending on the voltage-applying electrodes 22V is removed so as to expose the feeding lines 33. The feeding lines 33 are typically composed of copper (Cu), and the exposed portions thereof have gold-plating layers 34 formed on the front and rear surfaces thereof. The resin base 31 and the feeding lines 33 both extending on the voltage-applying electrodes 22V are held to the FPC board 30 before being connected to the piezoelectric elements 22. The feeding lines 33 have an example thickness of about 10 to 20 μm.

[0019]

In this embodiment, the feeding line 33 of the FPC board 30 and the voltage-applying electrode 22V are connected to

each other by ultrasonic bonding such that the feeding line 33 abuts against the voltage-applying electrode 22V, and an ultrasonic probe 41 is brought into contact with the voltage-applying electrode 22V from above the same. According to ultrasonic bonding, the gold-plating layers formed on the front and rear surfaces of the feeding line 33 are dispersed so that the feeding line 33 is bonded to the electrode 22V.

[0020]

Figs. 10 to 12 illustrate a modification of the first embodiment (second embodiment) in which the feeding line 33 and the voltage-applying electrode 22V are connected to each other with a gold ball 42 by gold-ball bonding instead of ultrasonic bonding. The gold bonding is well known. The feeding lines 33 are less damaged according to the second embodiment than according to the first embodiment achieved by ultrasonic bonding and are hence more reliably connected.

[0021]

Figs. 13 to 17 illustrate a third embodiment of the present invention. A portion of the resin base 31 of the FPC board 30 extending on and under the feeding line 33 lying on the voltage-applying electrode 22V of each piezoelectric element 22 is partially removed. As illustrated in the figures by way of example, the portion of the resin base 31 is partially removed in a round form so as to have a ring-shaped remainder 31A remaining on the front and rear surfaces of the feeding line 33, and a portion of the feeding line 33 lying other than inside the ring-shaped remainder 31A is covered and reinforced by the resin base 31 (typically

composed of polyimide). In other words, the feeding line 33 is not broken unless the feeding line 33 is broken. The feeding line 33 has a through-hole 33A formed inside the ring-shaped remainder 31A. Although the shape of the remainder portion is not necessarily circular, it is advantageous from the viewpoint of strength that the remainder portion is formed in a closed loop. An example inner diameter of the ring-shaped remainder 31A is about 0.2 to several millimeters.

[0022]

In this embodiment, the power supplying line 33 of the FPC board 30 and the voltage-applying electrode 22V of the corresponding piezoelectric element 22 are connected to each other such that the ring-shaped remainder 31A is arranged to lie on the voltage-applying electrode 22V, and a gold ball 43 is inserted through the through-hole 33A of the feeding line 33 toward the voltage-applying electrode 22V so as to connect the power supplying line 33 and the voltage-applying electrode 22V to each other. According to this embodiment, since the feeding line 33 is reinforced by the ring-shaped remainder 31A of the resin base 31, the feeding line 33 is rarely broken, thereby achieving manufacturability and reliability at the same time.

[0023]

Figs. 18 and 19 illustrate an embodiment in which the feeding line 33 and the voltage-applying electrode 22V are connected to each other with a stud bump instead of gold-ball bonding. The voltage-applying electrode 22V has a stud bump

45 previously accreted thereon by discharging a gold ball. The stud bump 45 has a large diameter portion 45a firmly fixed to the voltage-applying electrode 22V and a small diameter portion 45b formed on the large diameter portion 45a, and the shape of the stud bump 45 is determined depending on the shape of a capillary for a gold ball. The feeding line 33 of the FPC board 30 and the voltage-applying electrode 22V are connected to each other such that, after the small diameter portion 45b of the stud bump 45 is inserted through the through-hole 33A of the feeding line 33, an ultrasonic probe is brought into contact with the small diameter portion 45b from above the same so as to crush the small diameter portion 45b for establishing the connection. In particular, a sufficient bonding area is provided for the feeding line 33 and the voltage-applying electrode 22V in this embodiment, thereby improving reliability of the connection.

[0024]

In the embodiment of the connection performed by ultrasonic bonding as illustrated in Figs. 4 to 9, although the gold-plating layer 34 must be formed on the front and rear surfaces of the feeding line 33, the gold-plating layer 34 is not a must for the connection according to the other embodiments. However, the gold plating 34 has an advantage in improving the electrical and mechanical bonding strength.

[0025]

Technologies for forming the trace lines 32 and the feeding lines 33 on the resin base 31 of the FPC board 30 in accordance with an arbitrary pattern have already been

established, and also, the resin base 31 once formed can be easily removed in accordance with an arbitrary pattern by a physicochemical method such as etching. To be specific, for example, by using a reactive ion etching (RIE) device so as to react ion gas in its chamber with the resin base, a part of the resin base is removed so form the pattern.

[0026]

[Advantages]

According to the present invention, a magnetic head actuator which is equipped with a finely movable tracking device including piezoelectric elements and which facilitates wiring to the piezoelectric element while reducing problems such as wire breakage and continuity defects is provided.

[Brief Description of the Drawings]

[Fig. 1]

Fig. 1 is a plan view of an overall HDD equipped with a magnetic head actuator according to the present invention.

[Fig. 2]

Fig. 2 is a rear view of the sole magnetic head actuator (swing arm) shown in Fig. 1.

[Fig. 3]

Fig. 3 is a sectional view taken along the lines III-III indicated in Fig. 2.

[Fig. 4]

Fig. 4 is an enlarged plan view of an essential part of the magnetic head actuator according to a first embodiment of the present invention.

[Fig. 5]

Fig. 5 is a sectional view taken along the line V-V indicated in Fig. 4.

[Fig. 6]

Fig. 6 is a sectional view taken along the lines VI-VI indicated in Fig. 4.

[Fig. 7]

Fig. 7 is a sectional view taken along the lines VII-VII indicated in Fig. 4.

[Fig. 8]

Fig. 8 is a schematic view illustrating a connecting state according to the first embodiment, of a feeding line of an FPC board and a voltage-applying electrode of a piezoelectric element.

[Fig. 9]

Fig. 9 is a sectional view of the connecting state.

[Fig. 10]

Fig. 10 is a schematic view illustrating a connecting state according to a second embodiment of the present invention, of the feeding line of the FPC board and the voltage-applying electrode of the piezoelectric element.

[Fig. 11]

Fig. 11 is a schematic view illustrating a connecting state after the connection is completed.

[Fig. 12]

Fig. 12 is a sectional view illustrating the connecting state.

[Fig. 13]

Fig. 13 is an enlarged plan view of an essential portion

of the magnetic head actuator according to a third embodiment of the present invention.

[Fig. 14]

Fig. 14 is an enlarged plan view of a resin-base-removed portion of the FPC board.

[Fig. 15]

Fig. 15 is a schematic view illustrating a connecting state according to a third embodiment of the present invention, of the feeding line of the FPC board and the voltage-applying electrode of the piezoelectric element.

[Fig. 16]

Fig. 16 is a sectional view illustrating a connecting state before the connection is performed.

[Fig. 17]

Fig. 17 is a sectional view illustrating a connecting state after the connection is completed.

[Fig. 18]

Fig. 18 is a schematic view illustrating a connecting state according to a fourth embodiment of the present invention, of the feeding line of the FPC board and the voltage-applying electrode of the piezoelectric element.

[Fig. 19]

Fig. 19 is a schematic view illustrating a state in which the connection is on its way.

[Fig. 20]

Fig. 20 is a sectional view illustrating a connecting state after the connection is completed.

[Reference Numerals]

11: rotating axis

12: hard disk

13: coarse rotating axis

14: actuator

15: record-playback circuit

16: control circuit

20: swing arm

20S: spaces

21: magnetic head

22: piezoelectric elements

22V: voltage-applying electrodes

22G: ground electrodes

24: insulating non-shrinkable resin

25: electrically conductive resin

30: FPC board

31: resin base

31A: ring-shaped remainders

32: trace lines

33: feeding lines

33A: through-holes

34: gold-plating layers

41: ultrasonic probe

42: gold balls

43: gold balls

45: stud bumps

45a: large diameter portions

45b: small diameter portions